

SAIC/STM Power Input to CSP Peer Review

By

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Supported by SunLab

SunDish Business Goals/Programs

- To **Verify** the **Reliability**, **Cost** and **Performance** of the SunDish needed for unsubsidized sales to **Grid Tied** and **Remote Markets by 2006**.
- USJVP Started 1993 ended 1998,
 - \$40M industry \$12M DOE , Built 5 Systems
- Operation and Reliability Improvement
 - Funding \$1.8M per year, with 4 operating systems.
- Private investment
 - STM Power raised \$25M of private capital in 2001
 - SAIC raised \$4M of private capital in 2001

SAIC/STM Solar Dish/Stirling



THE SunDish at Sunlab NREL facility
in Golden, Colorado
October 1998 – Present

THE SunDish at the Pentagon
April 1998 – October 1998



THE SunDish at the Salt River
Project on the Pima-Maricopa
Indian Community Landfill in
Phoenix, Arizona
September 1999 – Present



THE SunDish Systems at the APS STAR Facility
in Phoenix, Arizona
July 1999 – Present



THE SunDish System at UNLV
in Las Vegas, Nevada
August 2001 – Present

O&M Project Objectives

Planned

- Achieve 200 hours of autonomous operation for each system without incident.
- Demonstrate hybrid operation with multiple fuel sources
- Achieve 90% system availability for all DOE-funded systems.
- Collect reliability and O&M cost and performance data for input to SunLab dish/engine reliability database.

Achieved

- 110 hours on SRP
- Hybrid operation with natural gas, landfill gas, & hydrogen
- 90% on one system, 70% overall
- Collected critical data to identify root causes of unreliability and project reliability growth

Approach Phase 1

Planned

- Investigate and correct design deficiencies
 - optical stability and quality of concentrator
 - engine-specific faults (actuator, hybrid combustion system, instrumentation and controls).
- Operate APS and SRP
 - 70% availability on at least one system
 - 80% of nominal performance
- Reliability Database SunLab

Achieved

- Corrected flaws
 - Stiffened optical bench, umbrella struts & no bolt slip.
 - Upgraded controls and hybrid burner.
- O&M
 - 65% Average
 - 85% Performance
- Root Causes Identified

Approach Phase 2

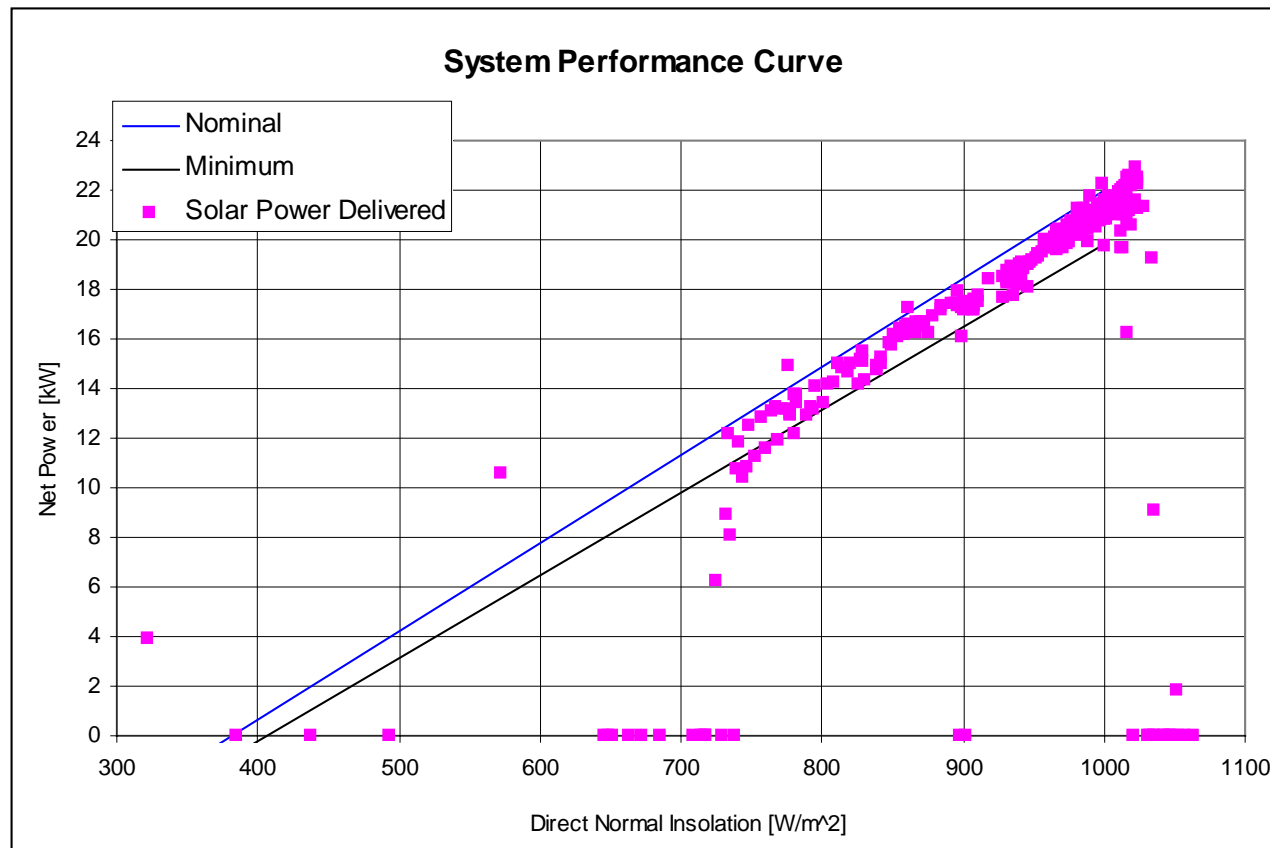
Planned

- Maintain high availability (>90%) three systems
- Component engineering
 - Controls not reliable
 - Focus unstable
 - Hydrogen from gas bottles diffuses out
 - Stronger Drives
 - Hydrogen Leaks

Achieved

- Have reached 90% for 30 day periods, understand how to do it consistently
- Controls allow autonomous operation with remote call in.
- Focus control stabilized, but higher tracking accuracy needed
- Hydrogen make up from water splitting and hydride pumping demonstrated for hot fill
- Advance high moment drive ready to prototype
- Better alignment and sealing

SunDish On-Sun Performance



Salt River Project

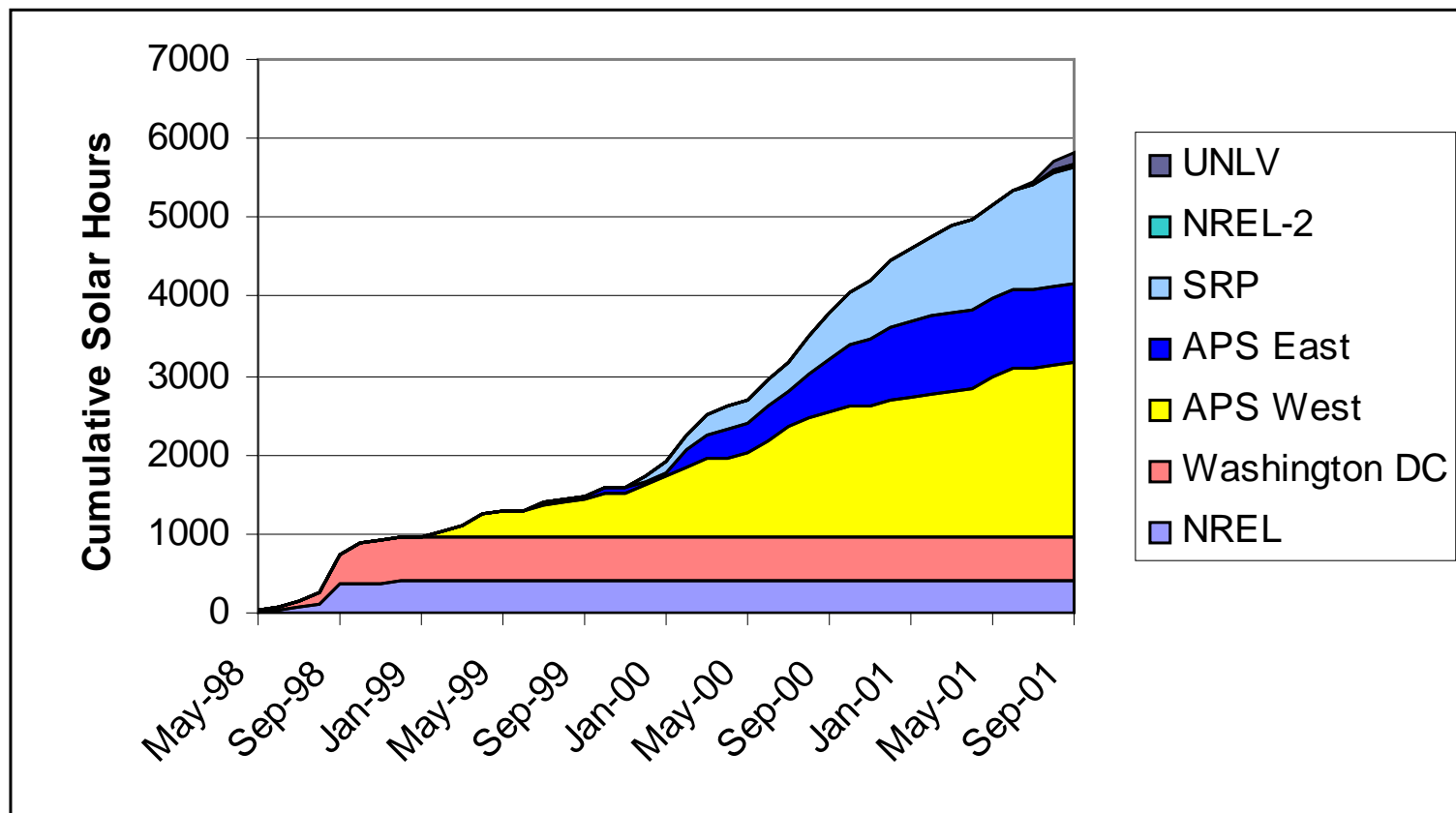
Solar/ Landfill Gas Hybrid for August '01

- Power observed **Solar 18.6 kW @ 932 W/m²**, Power Expected Solar 19.5 kW @ 932 W/m²
- Power observed **Landfill Gas 21.9 kW** , Power Expected Landfill Gas 25 kW
- **99% Available**
- 15 Days of Operation
- **1,399 kWh Produced**; 1,734 kWh Expected or 80% of planned kWh
- Several minor incidents, which were repairable in hours.

Accomplishments

- 5,800 hours of operation on all three systems (since May 1998)
- Hybrid operation on all three systems (25 kW demonstrated on APS West)
 - Natural gas - APS East and APS West
 - Hydrogen - APS West
 - Landfill gas - SRP
- Independent measure of emissions validated STM projections
- Much improved availability over prior years

Demonstrated SunDish Performance



UNLV

Solar only Dish for August 2001

- Power Observed Solar **19.3 kW @ 927 W/m²**, Power Expected Solar 19.4 kW @ 927 W/m²
- **88% Available**
- 15 Days of Operation
- **1,225 kWh Produced;** 1,412 kWh Expected, or 87% of planned kWh
- Two major incidents, which were repairable in hours.

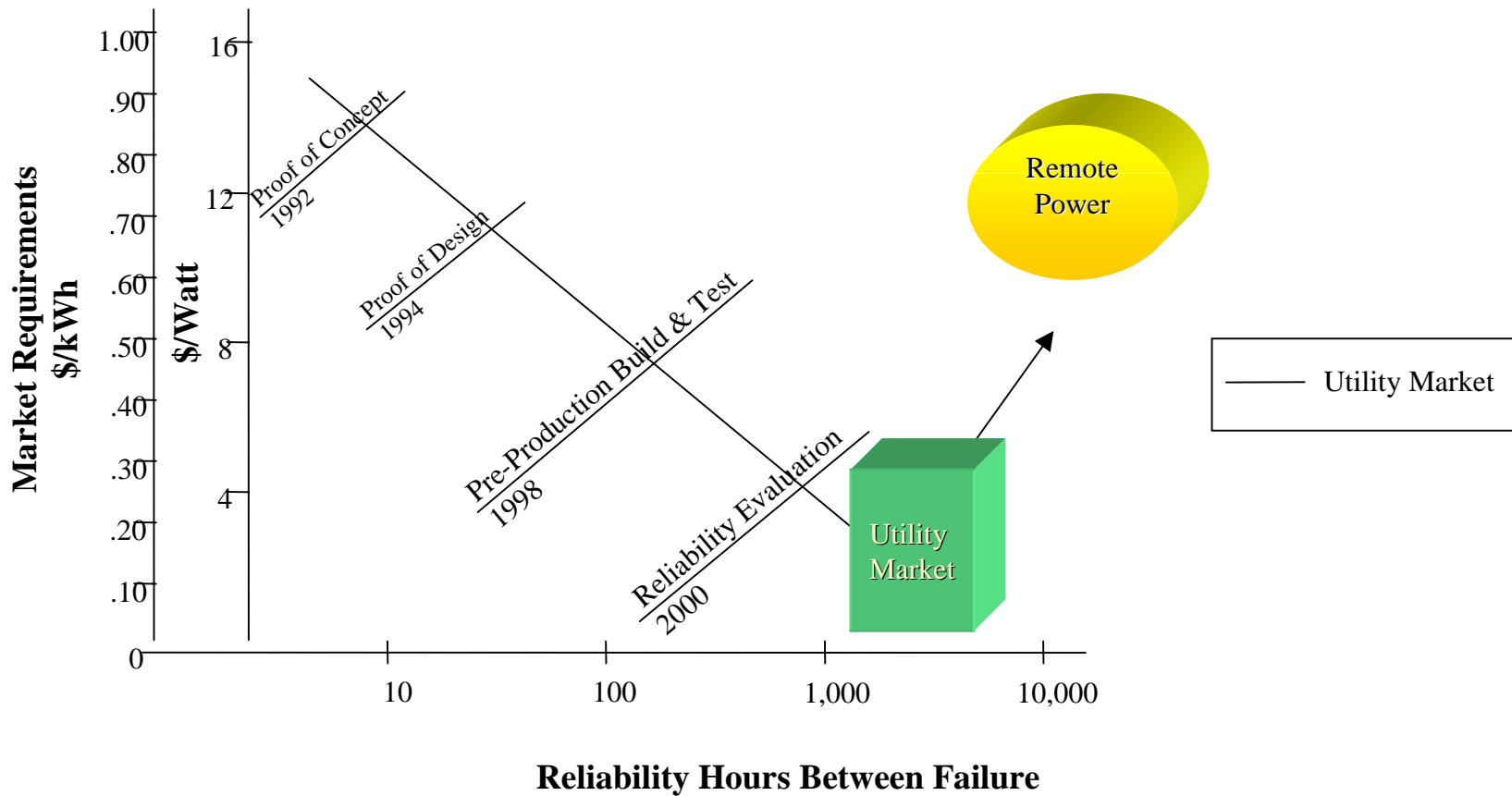
SunDish Reliability Potential

	\$10/W	\$4/W	\$3/W	\$2/W
	1 System	200 Sys.	2,000 Sys.	20,000 Sys.
	Baseline 2001	5MW/ Year	50MW/ Year	500MW/ Year
RELIABILITY				
System Availability	80%	95%	99%	99.99%
MTBF	40	2,000	10,000	20,000
Service Costs	10¢/kWh	2¢/kWh	1¢/kWh	.5¢/kWh

SunDish Performance Potential

	\$10/W 1 System Baseline 2001	\$4/W 200 Sys. 5MW/ Year	\$3/W 2,000 Sys. 50MW/ Year	\$2/W 20,000 Sys. 500MW/ Year
PERFORMANCE IMPROVEMENT OPTIONS				
Heat to Electricity (Engine Efficiency %)	36%			
Flux Smoothing		39%	39%	
Ceramic heater heads				50%
Higher Average Reflectance	87%	90%	91%	92%
Less soiling(%)				
Mirror Modules (Intercept %)				
Membrane Variable Focus	90.30%			
Fixed Focus Parabolic		95%	98%	98%
Smaller Aperture	85%	95%	95%	95%
(Absorbed Power %)				
Increase Mirror Area (m ²)	113.5	144	144	144
SYSTEM PERFORMANCE				
Annual Output Estimated (kWh/Year)	40,877	67,000	67,600	70,600
System Weight (Lbs)	18,000	12,000	10,000	9,500
Performance Factor (kWh/Lb/Year)	2.27	5.58	6.76	7.43

SunDish market requirements are achievable



How are we getting there?

- Most technical and commercial goals are being achieved by leveraging private sector investment
- Potential to build the most reliable and cost effective dish/Stirling systems by leveraging achievements in stationary power
 - 10 *alpha* stationary PowerUnits shipped in 2001
 - 50 - 75 *beta* stationary PowerUnits scheduled for 2002
 - Commercial production of stationary PowerUnits in 2003
- Dish redesign in progress
- Need a 1 MW dish/Stirling project to demonstrate system reliability growth (e.g. the proposed 1 MW Nevada project)
- Need SunLab to do key materials and components research, i.e. new corrosion resistant mirror materials, high temperature alloys, optical testing, etc.

STM product portfolio allows achievement of technical and commercial goals



Stationary Power

- Grid parallel
- Black start
- Oil, Gas, CBM



Hybrid Vehicle

- Buses
- Vans
- APUs



Renewables

- Solar
- Landfill gas
- Biogas



Industrial Waste Heat



Biomass

- Animal waste
- Farm waste



Residential and Small C & I

- 10 kW
- 2 kW

25 kW PowerUnit™

Demonstrated Performance

- Electric output
 - 25 kWe
 - 480 VAC, 3-Phase, 60 Hz
- Heat output
 - 44 kWth
 - 150,000 BTU/hr: 130° F
 - Coolant flow: 25 GPM
 - Coolant: 50% glycol
- Fuel consumption measured at 25 kWe
 - 315 SCF/hr of natural gas
 - 30% net electric efficiency
 - 80% efficiency CHP
- Noise level at 3 feet
 - 68 dBA



Length 6' 6" Height 3' 6" Width 2' 6"

Vertical footprint 8.8 feet

Continued DOE support essential for dish/Stirling commercial success

- Need DOE to continue supporting the 25 kW dish system reliability growth by operating what we have in the field.
- Need DOE 80% support for 1MW and 20% support for next 5MW and 5% support for next 50MW. **Then we can launch at below \$4/Watt.**

Attachment 1

STM Supporting Material

STM Power Overview

- STM Power is the world's leading manufacturer of reliable, low cost, environmentally clean external combustion (Stirling cycle) products in the 25 kW range for distributed generation
- Five of the toughest venture capitalists invested \$25 Million in the Company in March 2001 because they believe in the commercial viability of the Company's products
- Development of reliable, low cost stationary power products for the DG market will result in the development of high quality, reliable and inexpensive solar PCS products and lower the cost of dish/Stirling systems.

SAIC/STM Dish/Stirling

Salient features

- Dish/Stirling is distributed generation (“DG”) for the solar world
 - No T&D costs
 - Efficient use of land (10 systems per acre)
 - The only available solar-hybrid system in the market
 - Return on capital 24 hours per day

Dish/Stirling

Outstanding issues addressed

- Use of 1998 model year equipment
- Many of the reliability issues for STM engine have been addressed in *alpha* and should be resolved in *beta*:
 - H2 replenishment
 - Heater head redesign
 - Cooling system redesign
 - Swashplate

STM

Status and Direction

- Build the most reliable and cost effective dish/Stirling systems by leveraging achievements in stationary power
 - 10 *alpha* stationary PowerUnits shipped in 2001
 - 50 - 75 *beta* stationary PowerUnits scheduled for 2002
 - Commercial production of stationary PowerUnits in 2003
- Need for a 1,000 kW dish/Stirling demo project

Major milestones attained

- Demonstrated cost reduction plan with Ricardo
- Focused approach to increase PowerUnit net efficiency to 40%
- Ultra Low NOx emissions, demonstrated 8 ppm (0.41 lbs/MWh)
- Business agreements (Ricardo, Proton, Bosal, DTech, STK)
- Alpha test program commenced
- Sale of beta units (34 of 50), may extend beta sales
- Additional solar unit commissioned
- Management recruitment

STM Features

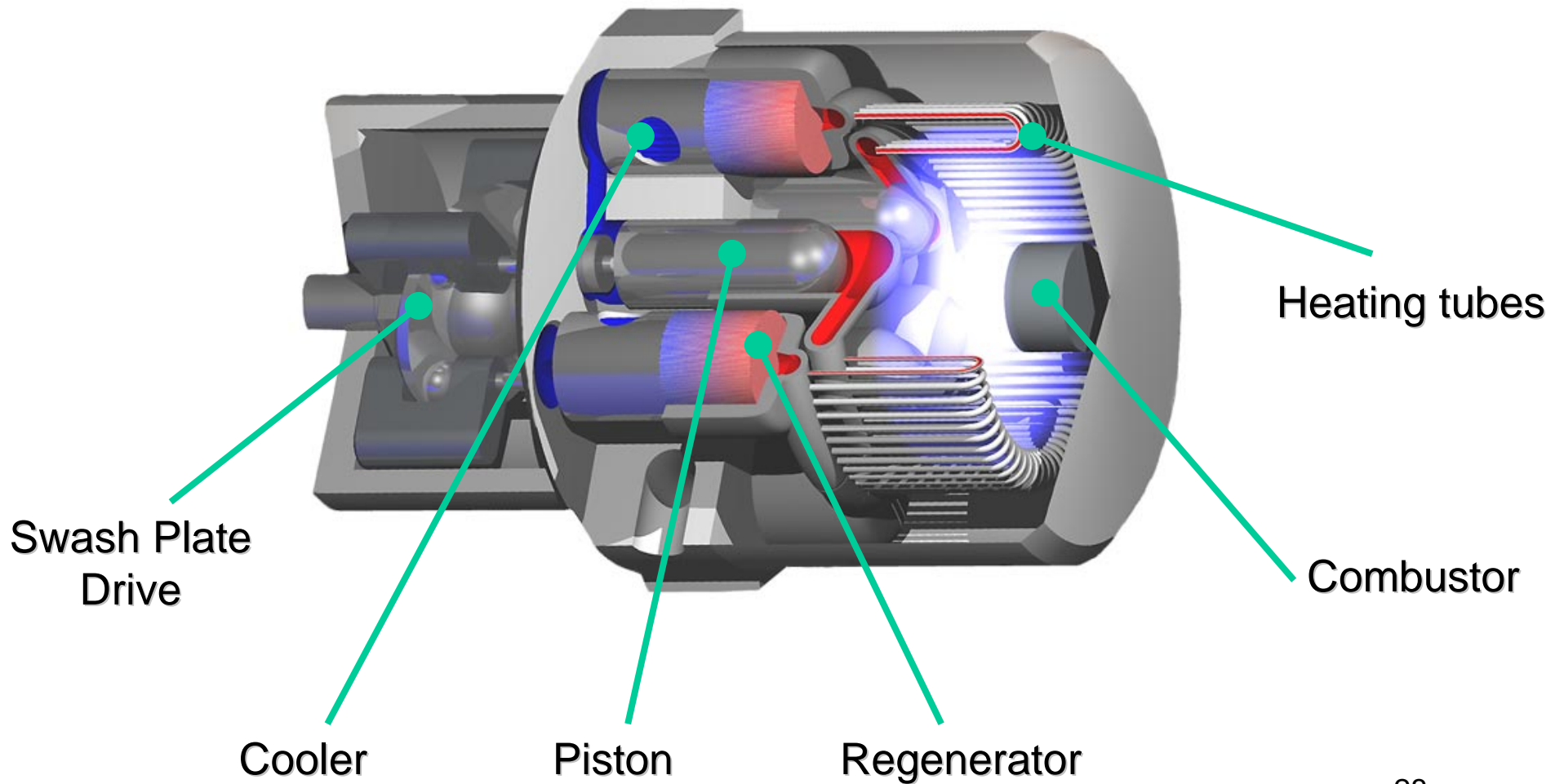
- **Technology and Products**
 - Leader in Stirling-cycle technology
 - Prime mover, not just a generator
 - Cost competitive on price per kWh
 - Current net efficiency 30% (25 kW), goal 40% (33 kW)
 - Fuel versatility (gaseous, liquid, heat and renewables)
 - Long design life (50,000 hours)
 - Low maintenance (10,000 hours)
 - Scalable (2 kW to 500 kW)
 - Socially responsible (ultra low emissions)
 - Convenient (small and quiet)
 - Heat output concentrated to hot water for CHP

STM Features (cont...)

- **Business**
 - Automobile-style cost reduction model to \$400 per kW
 - Focused on low-end of micro-generation market
 - Base load, peak or standby
 - Estimated gross margin by 2003
 - Intellectual property protection
 - Experienced management
 - Industry-savvy Board
 - Strong investor base

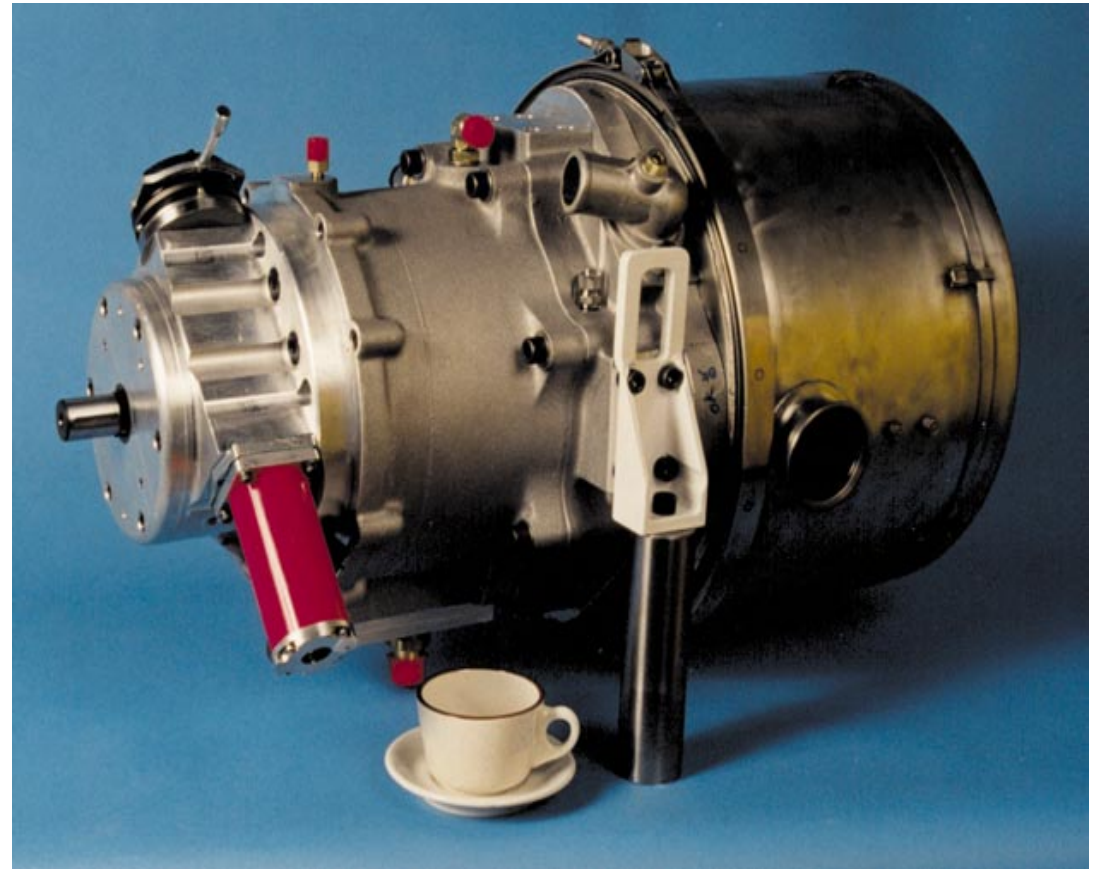
Technology

STM Double-Acting Engine



STM 4-120 Engine

- Bore x Stroke
 - 57 x 47 mm
- Displacement
 - 480 cc (29.3 in³)
- Industrial (Demonstrated)
 - 45 hp/1800 rpm
 - 94 hp/liter or 1.5 hp/in³
- Automotive (Projected)
 - 120 hp/6000 rpm
 - 250 hp/liter or 4 hp/in³
- Weight (Naked Engine)
 - 136 kg

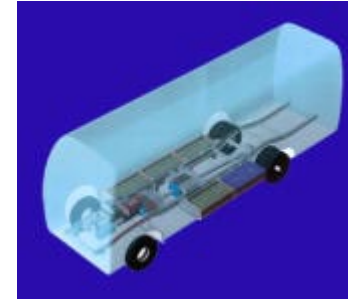


Portfolio of STM Products



Stationary Power

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Business

Investment and R&D to Date

Previous private equity	\$35 million
GM hybrid R&D program	17 million
DOE/Sandia/NREL cost sharing	6 million
March 2001 private equity offering	<u>\$25 million</u>
	\$83 million

Strong Investor Base

Beacon Group *

Nth Power *

Micro Gen Fund (Arete) *

JP Morgan Partners

Bosal Group (Belgium) *

Philips Family (Netherlands) *

Singapore Technologies *

DTE Energy Technologies

Ricardo, plc (UK)

Employees (20%)

Experienced Management

Lennart N. Johansson, President, CEO, and Director. 30 years experience. Considered the world's leading expert in external combustion (Stirling-cycle) engine technology. Former President of McDonnell Douglas' Stirling Power Systems.

John J. McKenna, CFO and Director. 25 years in energy financing at Citibank, Lehman Bros., Dean Witter and most recently as Managing Director of the Energy Technologies Group of PricewaterhouseCoopers Securities.

Benjamin Ziph, Vice President Engineering. 20 years experience with external combustion technology at Philips Laboratories, Ford-Philips Stirling and most recently at DaimlerChrysler.

Mark T. Kuntz, Sales and Marketing. Previously VP of Marketing for Capstone Turbine Corporation; VP and GM - Unicom Distributed Energy and 11 years at Lennox Industries.

Diane Miller, Vice President, Treasurer, Controller. Formerly SVP Controller of Domino's Pizza LLC and CFO, American Dental Technologies.

Edward N. Carlson, Director - Manufacturing. 18 years experience in operations management, production manufacturing and manufacturing process development. Prior experience at EG&G Inc. and Pratt & Whitney.

Stefan Johansson, Director - Laboratory and Quality Control. 17 years of experience working with external combustion engines.

Himesh Dhungel, PhD, Director, Business Development. 12 years experience, World Bank, PSE&G, PricewaterhouseCoopers Securities.

Randy Thomas, General Manager, Waste Heat. Formerly with Drever Corporation.

Himesh Dhungel, PhD

Dr. Dhungel joined STM Power in May 2001 as Director of Business Development. In this capacity, he is responsible for identifying markets for STM products, developing strategic relationships with customers, distributors and vendors, and crafting corporate and business strategies.

Prior to joining STM, Dr. Dhungel was with PricewaterhouseCoopers Securities in their Energy Technologies Investment Banking group where he led the research team and also provided financial advisory, corporate and project finance, and investment banking services to Fortune 500 clients and small start-up technology companies.

Dr. Dhungel brings a diverse energy sector experience, having previously worked at PSE&G--a utility in New Jersey, the World Bank, the United Nations and several small firms, both in the U.S. and overseas. Dr. Dhungel's expertise is energy economics, finance and business strategy.

Dr. Dhungel holds a Ph.D. in energy economics from the University of Pennsylvania, a Masters degree in Energy Technology from the Asian Institute of Technology, Thailand and an undergraduate degree in Electrical Engineering from Manipal Institute of Technology, India. He is a member of International Association for Energy Economics.